Homework Experiment 1: Introduction to GNU Radio

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Course: Digital Communication · **Instructor:** Prof. Dr. İsmail Kaya · **Due date:** to be announced in class

In this homework you will install GNU Radio 3.8.2 and use GNU Radio Companion (GRC) to generate BPSK, QPSK and 16-QAM signals. You will observe them in the time, constellation and frequency domains and study the effect of pulse shaping and noise. You will submit one PDF report and your .grc files by e-mail.

Preparation

1. **Install GNU Radio 3.8.2.** Download the Windows (64-bit) installer from the GCN Development GNU Radio page. Choose the second installer in the list: GNU Radio 3.8.2.0, built with Python 3.9. This package also installs the gr-osmosdr drivers and tools for the HackRF One, the SDR available in our laboratory.
2. **Learn the basics.** Watch introductory videos on GNU Radio Companion and on using the HackRF One with GNU Radio. Two examples are given below; they are only starting points, so search for and watch further videos yourself.
    - Introductory GNU Radio Companion tutorial
    - GNU Radio Companion tutorial, Part 1 (recorded in 2012 with an older GNU Radio version, so some blocks look different)
    - The official GNU Radio tutorials, especially "Your First Flowgraph" and "Runtime Updating Variables"

All tasks below are simulations; no SDR hardware is needed for this homework.

Tasks

All five tasks are compulsory. Use a variable `samp_rate` = 32000 (the GRC default) unless a task says otherwise. Label every screenshot with the modulation type and the parameter values used.

Task 1 – Modulated signal in the time domain

Build the flowgraph Random Source → Throttle → Constellation Modulator → QT GUI Time Sink.

- Generate a random binary data stream with the Random Source block (Output Type: Byte, Minimum: 0, Maximum: 256, so that every byte carries 8 random bits).
- Pass the stream through a Throttle block set to `samp_rate`.
- Modulate it with BPSK, QPSK (4-QAM) and 16-QAM, one modulation at a time.
- Display the I (real) and Q (imaginary) components on the QT GUI Time Sink. Take a screenshot for each modulation with the Windows Snipping Tool (Win + Shift + S) and comment on the differences.

Task 2 – Constellation diagram

Connect the same modulator output to a QT GUI Constellation Sink. Take a screenshot for BPSK, QPSK and 16-QAM, and comment on the number and positions of the constellation points.

Task 3 – Pulse-shaping filter with β = 0.3 and β = 0.7

The Constellation Modulator contains a root-raised-cosine (RRC) low-pass pulse-shaping filter. Its roll-off factor β is set by the Excess BW parameter (default 0.35).

- Run the flowgraph with β = 0.3 and with β = 0.7.
- Report the results using the time and constellation graphs.
- Add a QT GUI Frequency Sink and compare the occupied bandwidth. Theory gives a bandwidth of about (1 + β) × Rs, where the symbol rate Rs = samp_rate / (Samples/Symbol).

Task 4 – Flowgraph with a graphical user interface

Build one flowgraph whose GUI lets the user:

- adjust the data rate (QT GUI Range),
- select the modulation type: BPSK, QPSK or 16-QAM (QT GUI Chooser),
- select the display: time, constellation or frequency graph (QT GUI Tab Widget with three tabs).

Report screenshots of the flowgraph in GRC and of the running GUI.

Hint: the Constellation Modulator's parameters cannot be changed while the flowgraph is running. Build one modulator for each modulation type and switch between them with a Selector block (3 inputs, 1 output) whose Input Index is the chooser variable (0, 1, 2). With Samples/Symbol fixed, a QT GUI Range on `samp_rate` changes the data rate. To place a sink in a tab, set its GUI Hint to `tab@0`, `tab@1` or `tab@2`, where `tab` is the ID of the Tab Widget.

Task 5 – Noise added to the I/Q signal

Extend the Task 4 flowgraph by adding complex Gaussian noise to the modulated I/Q signal, with the noise amplitude adjustable from the GUI.

- Use a Noise Source (Output Type: Complex, Noise Type: Gaussian) and an Add block. Set the noise Amplitude to the variable of a QT GUI Range.
- Report the time, constellation and frequency graphs for several noise amplitudes.
- Compare how BPSK, QPSK and 16-QAM are affected by the same noise amplitude.

Useful blocks

The tasks need the GNU Radio 3.8 blocks below; find them with the search field of the GRC block library.

Block	Purpose	Key settings
Random Source	Random binary data stream	Output Type: Byte; Minimum: 0; Maximum: 256 (the maximum is exclusive)
Throttle	Limits the processing rate when no hardware is connected	Sample Rate: `samp_rate`
Constellation Object (variable)	Defines the constellation	Constellation Type: BPSK, QPSK or 16QAM

Block	Purpose	Key settings
Constellation Modulator	Maps bits to symbols and applies RRC pulse shaping	Constellation: ID of the Constellation Object; Samples/Symbol; Excess BW = β
QT GUI Time Sink	Time graph of I and Q	Type: Complex
QT GUI Constellation Sink	Constellation diagram	Number of Points: 1024 (default)
QT GUI Frequency Sink	Spectrum	Bandwidth: `samp_rate`
QT GUI Range	Slider that sets a variable	Default Value, Start, Stop, Step
QT GUI Chooser	Menu or radio buttons that set a variable	Options: 0, 1, 2; Labels: BPSK, QPSK, 16-QAM
QT GUI Tab Widget	Tabbed display area	Num Tabs: 3
Selector	Switches between inputs while running	Type: Complex; Num Inputs: 3; Input Index: chooser variable
Noise Source	Gaussian noise	Output Type: Complex; Noise Type: Gaussian; Amplitude: range variable
Add	Adds the noise to the signal	Type: Complex

Report and submission

Submit one PDF report and the .grc files of your flowgraphs by e-mail before the due date.

- Start the report with your name and student number.
- For each task, include the screenshots, each labeled with the modulation type and parameter values, and a short comment on what you observe.
- Send the e-mail to ikaya@ktu.edu.tr with the subject `Homework Experiment 1 – <student number> <name surname>`, for example `Homework Experiment 1 – 123456 Ali Yılmaz`.
- Only .pdf and .grc attachments are accepted.
- Submit before end of 6th December 2026